Solving Large Complex Problems

“Efficient and Smart Solutions for Large Models”
ANSYS Structural Mechanics Solutions offers several techniques
Current trends in simulation show an increased need for the computation of large models.
Larger model size for higher accuracy
Full assemblies for higher realism
Better design knowledge from design variations
Continuous variations of the parameters provides in-depth information
Even more performance is required!
High Performance Computing is a key component of the ANSYS offering.
High Performance Computing as an Enabler

Insight you can’t get any other way

It’s all about getting better insight into product behavior quicker!

HPC enables high-fidelity

- Include details - for reliable results
- “Getting it right the first time”
- CONFIDENCE by DESIGN!

HPC enables design exploration & optimization

- Consider multiple design ideas
- Optimize the design
- Ensure performance across range of conditions
High Performance Computing
A Software Development Imperative

- Clock Speed – Leveling off
- Core Counts – Growing
  - Exploding (GPUs)
- Future performance depends on highly scalable parallel software

Size of the model – how large is “large”?

![Graph showing speed up with different model sizes and number of CPUs.]

- Speed Up vs. Number of CPUs for different model sizes:
  - 1000 elements
  - 8000 elements
  - 64000 elements
  - 512000 elements

The graph illustrates the speed up achieved with increasing model sizes and the number of CPUs.
A simple and productive licensing scheme

ANSYS HPC Pack

ANSYS HPC Workgroup
Which part of the simulation is faster?
Not all steps of the simulation are parallel
How should I read speed-up curves?

This is the solver part – excellent scaling!

This is YOUR time (elapsed)
The right combination of algorithms and hardware leads to maximum efficiency
Shared Memory Parallel vs Distributed Memory Parallel
# Challenges and solutions for the distributed method

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient and relevant decomposition</td>
<td>Partitioning methods, Solver</td>
</tr>
<tr>
<td>Load Balancing</td>
<td>Partitioning methods, Solver</td>
</tr>
<tr>
<td>Speed</td>
<td>Hardware(Processors, Interconnects), Solver</td>
</tr>
<tr>
<td>Maximum Problem Size</td>
<td>Hardware (RAM), Solver</td>
</tr>
<tr>
<td>I/O to communicate between cores.</td>
<td>Hardware (Interconnects), MPI, Solver</td>
</tr>
<tr>
<td>I/O to write results and overflow files during solution.</td>
<td>Hardware (Disks, Interconnects), MPI, Solver</td>
</tr>
</tbody>
</table>
### Sparse or iterative solvers?

<table>
<thead>
<tr>
<th>Solver type</th>
<th>Distributed/Shared Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPARSE (direct)</td>
<td>DMP/SMP</td>
</tr>
<tr>
<td>PCG (Iterative)</td>
<td>DMP/SMP</td>
</tr>
<tr>
<td>LANB (direct, modal)</td>
<td>SMP</td>
</tr>
<tr>
<td>LANPCG (iterative, modal)</td>
<td>DMP/SMP</td>
</tr>
<tr>
<td>SNODE</td>
<td>SMP</td>
</tr>
</tbody>
</table>
Get it in-core!
Check the PCG level!
Balancing the load: a key to efficiency
A consequence for contact users

Avoid overlapping contact surface if possible

Define half circle as target, don’t define full circle

Define potential contact surface into smaller pieces
What could it look like on your model?

- 6 Mio Degrees of Freedom
- Plasticity, Contact
- Bolt pretension
- 4 load steps

1 HPC Pack

Design variations per day vs. Number of cores

- Shared Memory
- Distributed Memory
The Right Software Architecture for HPC

Off-the-shelf High-Performance Computing
ANSYS Remote Solve Manager: Workbench-based job submission with full portfolio support for Platform LSF, PBS Pro, and Microsoft Job Scheduler

Bundled third-party Message-Passing software with optimized performance (Intel MPI, Platform MPI) on gigE, 10gigE, or Infiniband cluster fabric.
Our HPC Partnerships

ANSYS maintains close technical collaboration with the leaders in HPC

This mutual commitment ensures that you get the most possible value from your overall HPC investment

Some current examples:

• Optimized performance on multicore processors from Intel, with R&D focused on Intel’s Many Integrated Core (MIC)
  • Over 60% performance boost for the latest Intel® Xeon® E5-2600 processor (Sandy Bridge) family compared to previous Intel (Westmere) generation

• GPU computing accelerates ANSYS Mechanical today, with very active R&D engagement with NVIDIA across full portfolio

• ANSYS and IBM – Optimized cluster and storage architectures for ANSYS
What do your peers say?

“By optimizing our solver selection and workstation configuration, and including GPU acceleration, we’ve been able to dramatically reduce turnaround time — from over two days to just an hour. This enables the use of simulation to examine multiple design ideas and gain more value out of our investment in simulation.”

- Berhanu Zerayohannes, Senior Mechanical Engineer, NVIDIA

Application: Deflection and bending of 3-D glasses
Software: ANSYS Mechanical
HPC Solution: From 60 hours per simulation to 47 minutes (77x speedup)
Business Solution: Ability to ensure robust performance of the 3-D glasses via examining multiple design ideas
Taking advantage of new hardware solutions: GPU

Distributed ANSYS 14.0 Total Simulation Speedups

- 4 CPU cores
- 4 CPU cores + 1 GPU

<table>
<thead>
<tr>
<th></th>
<th>4 CPU cores</th>
<th>4 CPU cores + 1 GPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>V13cg-1 (JCG, 1100k)</td>
<td>1.52</td>
<td>1.16</td>
</tr>
<tr>
<td>V13sp-1 (sparse, 430k)</td>
<td>1.16</td>
<td>1.70</td>
</tr>
<tr>
<td>V13sp-2 (sparse, 500k)</td>
<td>1.20</td>
<td>2.24</td>
</tr>
<tr>
<td>V13sp-3 (sparse, 2400k)</td>
<td>1.20</td>
<td>1.44</td>
</tr>
<tr>
<td>V13sp-4 (sparse, 1000k)</td>
<td>2.24</td>
<td>1.44</td>
</tr>
<tr>
<td>V13sp-5 (sparse, 2100k)</td>
<td>1.44</td>
<td></td>
</tr>
</tbody>
</table>
Speed-up from GPU technology

Vibroacoustic harmonic analysis of an audio speaker

<table>
<thead>
<tr>
<th>Cores</th>
<th>GPU</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>no</td>
<td>2.25</td>
</tr>
<tr>
<td>4</td>
<td>no</td>
<td>4.29</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>11.36</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>11.51</td>
</tr>
</tbody>
</table>

Distributed ANSYS Results (baseline is 1 core):
• With GPU, ~11x speedup on 2 cores!
• 15-25% faster than SMP with same number of cores

Windows workstation: Two Intel Xeon 5530 processors (2.4 GHz, 8 cores total), 48 GB RAM, NVIDIA Quadro 6000
**Speed-up from Multi-Node GPU technology**

*Linux cluster*: Each node contains 12 Intel Xeon 5600-series cores, 96 GB RAM, NVIDIA Tesla M2070, InfiniBand

*Results Courtesy of MicroConsult Engineering, GmbH*
ANSYS has a strong commitment to High Performance Computing.

HPC Capability and Throughput

Evolvement of HPC Developments at ANSYS

- 2009
  - Ideal scaling to 2048 cores (fluids)
  - Teraflop performance at 512 core (structures)
  - Parallel I/O (fluids)
  - Domain Decomposition introduced (HFSS 12)

- 2005 - 2006
  - Parallel meshing (fluids)
  - Support for clusters using Windows HPC

- 2001 - 2003
  - Parallel dynamic moving/deforming mesh
  - Distributed memory particle tracking

- 1998-1999
  - Integration with load management systems
  - Support for Linux clusters, low latency interconnects
  - 10M cell fluids simulations, 128 processors

- 1994 - 1995
  - Parallel dynamic mesh refinement and coarsening
  - Dynamic load balancing

- 1993
  - 1st general-purpose parallel CFD with interactive client-server user environment

- 1990
  - Shared Memory Multiprocessing for structural simulations

- 1980
  - Vector Processing on Mainframes

- 2011
  - Ideal scaling to 3072 cores (fluids)
  - Hybrid parallelization (fluids)
  - Network-aware partitioning (fluids)
  - Large finite antenna arrays (HFSS 14)
  - GPU acceleration with DMP (structures)

- 2007 - 2008
  - Optimized performance on multicore processors
  - 1st One Billion cell fluids simulation

- 2005 - 2007
  - Distributed sparse solver
  - Distributed PCG solver
  - Variational Technology
  - DANSYS released
  - Distributed Solve (DSO) HFSS 10

- 2004
  - 1st company to solve 100M structural DOF

- 1999 - 2000
  - 64bit large memory addressing
  - Shared memory multiprocessing (HFSS 7)

- 1994
  - Iterative PCG Solver Introduced for large structural analysis

- 1990
  - Shared Memory Multiprocessing for structural simulations

- 1980's
  - Vector Processing on Mainframes
High Performance Computing is dynamic, technology dependent.
Reduction techniques help reduce the CPU time and can help compute design variations more efficiently.
Submodeling is the solution when only a portion of the model matters.
The coarse model provides accurate deformations but inaccurate stresses.
The refined model(s) will provide accurate stresses.
From the coarse model to the submodel through results mapping

Displacements are mapped to the common boundary
Solving two models can be faster than solving a very detailed one
General Procedure

1. Create and analyze the initial model
2. Create the submodel
3. Perform cut boundary interpolation
4. Analyze the submodel
5. Verify that the distance between the cut boundaries and the stress concentration is adequate
Good practice: Verify the cut-boundary distance

Compare path plots at that location between the initial model and submodel.

Use the query option.

List the results.

Etc.
Submodeling with ANSYS Workbench
Submodelling in ANSYS WB

USAGE:
Insert this file as a command block into your WB model
(as part of the "Environment") and put the correct
input arguments in the first lines of the command block.

This block is to be executed once at the beginning.

HOW IT WORKS
The commands will create a "cut.node" file containing
all nodes on the cutting surfaces and for each load case of
the model a file called "cut1.cblo", "cut2.cblo", ... containing
the nodal displacements at this nodes for all load cases.
For each load case another command block is to be used, that
reads in the cut%4.cblo files

HINTS:
1) Make sure that your submodel has as many load steps as the
   complete model.
2) Define the parameters arg1 and comp according to your needs

21.11.2005 Martin Obermayr martin.obermayr@siemens.com
13.07.2009 Pierre Thieffry, modified for R12.01

AXCI: component name of the nodes in the cutting faces

arg1='NS_CUT'

DO NOT CHANGE THE LINES BELOW
store nodes on cutting surfaces
/prep7
cmexl,s,arg1
write,cut,node
allsel
save

read nodal displacements from model
fini
/clear
/pos1
/inquire,curdir,directory
*stat,curdir
*dim,fname,STRING,128
fname(1)=strcat(curdir(1),'\...\...\submodel')
resu,fname(1),db

/inquire,curdir,directory
*stat,curdir
*dim,fname,STRING,128
fname(1)=strcat(curdir(1),'\...\...\submodel')

Submodeling works for a variety of topologies and nonlinear models as well.
From a solid model to a solid model

Stress contour – full model

Stress contour – Submodel
From a shell model to a solid model

- **Initial geometry**
- **Defeatured shell model - deformations**
- **Solid submodel - stresses**
Nonlinearities can also be included

Submodel (line) vs refined full model (cross)

Coarse model
Substructuring or CMS allows for collaborative work or long transient simulations.
Static (Guyan)

- Guyan Reduction procedure
- Inertia forces are negligible compared to elastic forces
- Net result: the reduced stiffness matrix is exact, whereas the reduced mass and damping matrices are approximate

Note: Choosing master DOF is an important step in a reduced analysis, impacting accuracy of results
Component Mode Synthesis

- CMS is a type of substructuring which performs a modal analysis of a structure based on independent modal analyses of its parts.

- The synthesis involves making the components work together as a single structure by satisfying inter-component compatibility and equilibrium constraints.

- Master DOF are required only at interface nodes.
CMS with ANSYS Workbench
APDL macros embedded in the simulation tree for generation, use and expansion pass
Results are available through standard operations
Reduce solution time for harmonic and transient analyses
Comparing the accuracy of a CMS analysis to a standard one
Learn about the methods available in ANSYS Structural Mechanics Solutions.